

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
10 May 2001 (10.05.2001)

PCT

(10) International Publication Number  
WO 01/33129 A1

(51) International Patent Classification<sup>7</sup>: F16L 11/10

(74) Agents: KICE, Warren, B. et al.; Haynes and Boone, LLP, 901 Main Street, Suite 3100, Dallas, TX 75202 (US).

(21) International Application Number: PCT/US00/30464

(22) International Filing Date:  
4 November 2000 (04.11.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
60/163,908 5 November 1999 (05.11.1999) US  
09/706,070 3 November 2000 (03.11.2000) US

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

(71) Applicant (*for all designated States except US*): WELL-STREAM, INC. [US/US]; 1700 C Avenue, Port of Panama City, Panama City, FL 32401 (US).

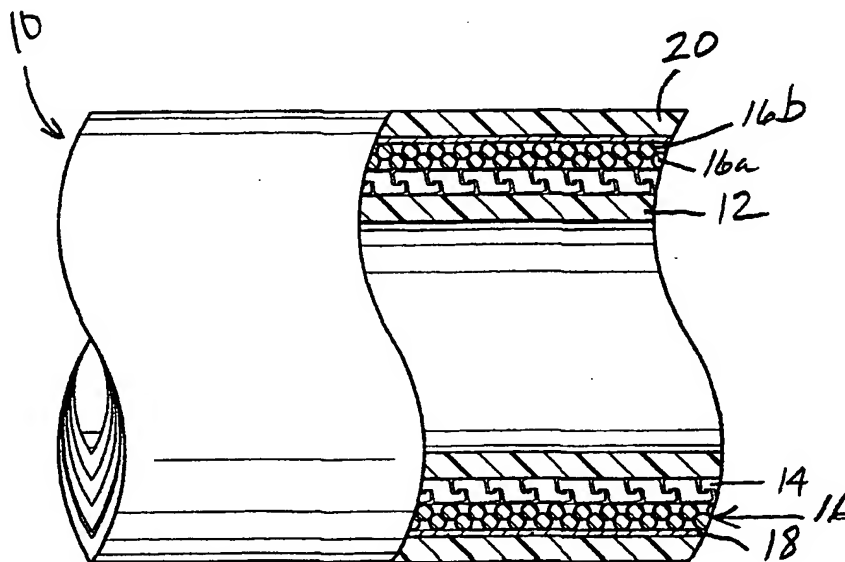
Published:

- With international search report.
- Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(72) Inventors; and  
(75) Inventors/Applicants (*for US only*): FRASER, Dana, J. [US/US]; 108 Limestone Lane, Panama City, FL 32405 (US). HOEFLING, Robert, G. [US/US]; 1009 West 28th Place, Panama City, FL 32405 (US). KALMAN, Mark, D. [US/US]; 2721 Longleaf Road, Panama City, FL 32405 (US). MCCONE, Alan [US/US]; 765 14th Avenue, San Francisco, CA 94118 (US).

(54) Title: FLEXIBLE PIPE AND METHOD OF MANUFACTURING SAME



(57) Abstract: A flexible pipe (10) and a method of manufacturing same according to which the pipe is formed by multiple layers (12, 14, 16, 18, 20) of different materials suitable for use in subsea and land-based applications.



WO 01/33129 A1

**FLEXIBLE PIPE AND METHOD OF MANUFACTURING SAME**

This application claims priority of provisional application S.N. 60/163,908 filed November 5, 1999.

The present invention relates to a relative low-cost flexible  
5 pipe formed by multiple layers of different materials and suitable  
for use in subsea and land-based applications.

**Brief Description of the Drawing**

Fig. 1 is a longitudinal sectional view of a flexible pipe  
according to an embodiment of the present invention.

10 Fig. 2 is a longitudinal sectional view of a flexible pipe  
according to another embodiment of the present invention.

Figs. 3A-3C are longitudinal sectional views of alternative  
embodiments of a layer of the pipes of the embodiments of Figs. 1 and  
2.

15 **Detailed Description**

With reference to Fig. 1, a flexible pipe according to an  
embodiment of the present invention is shown, in general by the  
reference numeral 10. The pipe 10 is formed by an inner tubular  
member, preferably in the form of a plastic sheath 12 for conveying  
20 fluid through its bore. The sheath may be formed in a conventional  
manner using polymers, or the like.

A layer 14 is wrapped around the sheath 12 and provides  
resistance to internal pressure, hydrostatic collapse and crush. The  
layer 14 is formed by helically wrapping a continuous metal strip,  
25 preferably formed of carbon steel, with adjacent windings being  
interlocked, to form a flexible layer that provides significant hoop  
and axial strength. The layer 14 is marketed by the assignee of the  
present invention, Wellstream, Inc., under the "Flexlok" trademark.

A wrapped wire assembly 16 extends over the layer 14 and  
30 consists of a series of wires 16a helically wrapped around the  
exterior of the layer 14 to form a first tensile layer, and an  
additional series of wires 16b wrapped around the first series of  
wires 16a to form a second tensile layer extending over the first  
tensile layer. The wires 16a and 16b have a substantially circular

cross section, and are wound at a relatively high lay angle to provide significant hoop strength and axial strength. Preferably, at least a portion of the wires 16a and 16b are formed by carbon steel with an anodic coating. It is noted that the layer 14 prevents the expansion of the sheath 12 into gaps formed between the wires of the tensile layers 16a and 16b.

One or more layers of a tape 18 are helically wrapped over the wire assembly 16. The tape 18 can be formed by plastic or metal and can be reinforced with glass, metal or a stronger plastic. Although not shown in the drawings, it is understood that the tape 18 can also extend between the layer 14 and the wire assembly 16, and between the series of wires 16a and 16b.

A protective outer insulative sheath 20 extends over the tape 18 and is preferably extruded over the tape 18 in a conventional manner, with the tape providing a smooth surface for the extrusion. The sheath 20 is optional and is required only when the tape 18 is inadequate to protect the remaining components of the pipe 10.

Fig. 2 depicts a pipe 10' that is similar to the pipe 10 of Fig. 1 and includes some components of Fig. 1 which are given the same reference numerals. In the embodiment of Fig. 2, a wrapped wire assembly 26 extends over the layer 14 and consists of a series of wires 26a and 26b which are substantially rectangular in cross section. The wires 26a are helically wrapped around the exterior of the layer 14 to form a first tensile layer, and the wires 26b wrapped around the first series of wires 26a to form a second tensile layer extending over the first tensile layer.

According to an embodiment of the method of the invention, the rectangular profile of the wires 26a and 26b is achieved by unwinding the coiled wires from a mandrel, or the like, and passing the wires through opposed rollers which flatten the wires to a substantially rectangular cross section.

According to an alternate method of forming the wires 26a and 26b an elongated sheet is payed out from a coil and a plurality of spaced cutters are placed in the path of the sheet to slit the sheet in to a plurality of wires. The cutters are spaced in a manner to

form a plurality of wires having a rectangular cross section.

Both of the above methods avoid the high expense of specialized rolling mills in which coils of round carbon steel wire are processed through repeated roll forming and heat treating operations.

5        Also, in the embodiment of Fig. 2 it is understood that wrapped tape, identical to the tape layer 18, can also extend between the layer 14 and the wire assembly 26, and between the series of wires 26a and 26b.

10        Also according to the embodiment of Fig. 2, an inner layer 28 is provided inside the sheath 12. The layer 28 is preferably formed by a plurality of helically wrapped, corrugated and/or interlocked strips to provide additional collapse and radial compression resistance. If the layer 28 is added, the sheath 12 would be extruded over the outer surface of the layer 24.

15        It is emphasized that both the wire assembly 26 and the layer 28 can be included in the pipe 10 and/or 10', or one can be included without the other.

20        Figs. 3A-3C are alternative embodiments of the layer 14 which can be used with the pipe 10 and/or the pipe 10'. Referring to Fig. 3A, a continuous metal strip 30, preferably of carbon steel, is helically wrapped around the adjacent inner member (not shown). Two adjacent inner windings are shown by the reference numerals 30a and 30b, and three adjacent outer windings are shown by the reference numerals 30c, 30d, and 30e, respectively. The wrapping of the strip 25 30 is such that the winding 30d overlaps the windings 30a and 30b, the winding 30c overlaps the winding 30a and its adjacent inner winding (not shown), and the winding 30e overlaps the winding 30b and its adjacent inner winding (not shown), and so on. The strip 30 is wound in this manner for the length of the pipes 10 or 10', and it is 30 understood that the number of radially spaced windings, and therefore the thickness of the layer thus formed can vary.

35        According to the embodiment of Fig. 3B, a continuous metal strip 34, preferably of carbon steel, is helically wrapped around the adjacent inner member (not shown). The strip 34 is shaped, or formed, in any known manner to form a cross section having a first

substantially horizontal inner portion 34a, and second substantially horizontal portion 34b that is spaced radially outwardly from the inner portion 34a, and a bent portion 34c extending between the portions 34a and 34b. The strip 34 is preferably of carbon steel and is helically wrapped around the adjacent inner member (not shown). The wrapping of the strip 34 is such that the portion 34b overlaps the inner portion of its adjacent winding, and the portion 34a is overlapped by the outer portion of its adjacent winding, to thus achieve an interlocking effect. The strip 34 is wrapped for the length of the pipes 10 or 10', and it is understood that the number of radially spaced windings, and therefore the thickness of the layer thus formed can vary.

According to the embodiment of Fig. 3C, a continuous metal strip 38, preferably of carbon steel, is helically wrapped around the adjacent inner member (not shown). The strip 38 is shaped, or formed, in any known manner to form a cross section having a convex portion 38a extending from a concave portion 38b. The wrapping of the strip 38 is such that the convex portion 38a overlaps the concave portion of its adjacent winding and the concave portion 38a is overlapped by the convex portion of its adjacent winding to thus achieve an interlocking effect. The strip 38 is wrapped for the length of the pipes 10 or 10', and it is understood that the number of radially spaced windings, and therefore the thickness of the layer thus formed can vary.

#### **Variations**

1. In each of the above embodiments, additional tensile layers of wires can be provided in addition to the series of wires 16a and 16b in the pipe 10 and the series of wires 26a and 26b in the pipe 10'.
2. The carbon steel strip layer 14 can be omitted from each of the above embodiments in which case the first tensile layer 16a would be wound directly onto the sheath 12.
3. If the carbon steel strip is omitted, as discussed in paragraph 2, above, an optional wrapped tape, similar to the tape 18 could be provided that extends between the sheath 12 and the first tensile layer 16a.

4. The adjacent windings of the strip forming the layer 14 do not have to be interlocked.

5. In extremely hostile environments, an outer layer similar to the layer 14 can be placed around the sheath 20 for added protection, in  
5 each of the embodiments.

6. In extremely hostile environments, an outer layer similar to the layer 14 can be placed around the sheath 20 for added protection.

It is understood that spatial references, such as "under", "over", "between", "outer", "inner" and "surrounding" are for the  
10 purpose of illustration only and do not limit the specific orientation or location of the layers described above.

Since other modifications, changes, and substitutions are intended in the foregoing disclosure, it is appropriate that the appended claims be construed broadly and in a manner consistent with  
15 the scope of the invention.

What is claimed is:

1. A flexible pipe, comprising:

an tubular member defining a longitudinal passage;

5 a plurality of wires wrapped around the exterior of the tubular member to form a first tensile layer; and

a plurality of wires wrapped around the exterior of the first tensile layer to form a second tensile layer;

10 at least one of the wires having a substantially circular cross section.

2. The pipe of claim 1 wherein the tubular member is in the form of an extruded plastic sheath.

3. The pipe of claim 1 further comprising at least one layer of tape extending between the tubular member and the first tensile layer.  
15

4. The pipe of claim 1 further comprising at least one layer of tape extending between the first tensile layer and the second tensile layer.

5. The pipe of claim 1 wherein the wires are wrapped helically around the exterior of the tubular member.  
20

6. The pipe of claim 5 wherein the wires of the second tensile layer are wrapped in helically in an opposite direction to the wires of the first tensile layer.

7. The pipe of claim 1 wherein each wire has a coating of anodic material.  
25

8. The pipe of claim 1 wherein each wire has a coating of plastic material or paint.
9. The pipe of claim 1 wherein each tensile layer extends from one end of the pipe to the other end thereof.
- 5 10. The pipe of claim 1 further comprising an outer sheath extending over the second tensile layer.
11. The pipe of claim 10 further comprising at least one layer of tape extending between the second tensile layer and the outer sheath.
12. The pipe of claim 1 further comprising a metal strip extending  
10 between the tubular member and the first tensile layer.
13. The pipe of claim 12 wherein the strip is helically wrapped over the tubular member.
14. The pipe of claim 13 wherein the adjacent windings of the strip are interlocked.
- 15 15. The pipe of claim 13 wherein the cross section of the strip has a substantially horizontal inner portion, a substantially horizontal outer portion that is spaced radially outwardly from the first portion, and a bent portion extending between the first and second horizontal portions.
- 20 16. The pipe of claim 15 wherein the wrapping of the strip is such that outer portions of the strip overlap the corresponding inner portions of their adjacent windings, and the inner portions of the strip are overlapped the corresponding outer portions of their adjacent windings to achieve an interlocking effect.
- 25 17. The pipe of claim 13 wherein the cross section of the strip has a convex portion extending from a concave portion.

18. The pipe of claim 17 wherein the wrapping of the strip is such that the convex portions overlap the corresponding concave portions of their adjacent winding, and the concave portions are overlapped by the corresponding convex portion of their adjacent windings to  
5 achieve an interlocking effect.

19. The pipe of claim 12 further comprising at least one layer of tape extending between the metal strip and the first tensile layer.

20. The pipe of claim 1 further comprising a collapse-resistant, inner helical strip extending within the tubular member.

10 21. The pipe of claim 20 wherein the inner helical strip is corrugated.

22. The pipe of claim 20 wherein the inner helical strip is interlocked.

15 23. A method of manufacturing a pipe from coils of wires having a substantially circular cross section, the method comprising unwinding the wires from their respective coils, passing the unwound wires through rollers to flatten each circular cross section to a rectangular cross section as the wires unwind from the coil, and passing the wires from the rollers and wrapping them around a tubular  
20 member.

24. The method of claim 23 wherein the step of wrapping comprises wrapping a plurality of the wires around the exterior of the tubular member to form a first tensile layer, and further comprising wrapping a plurality of wires around the exterior of the first tensile layer  
25 to form a second tensile layer.

25. The method of claim 24 wherein the wires of the first tensile layer are wrapped helically around the exterior of the tubular member and wherein the wires of the second tensile layer are wrapped

helically around the first tensile layer in an opposite direction to the wires of the first tensile layer.

26. The method of claim 23 further comprising extruding an outer sheath over the second tensile layer.

5 27. The method of claim 23 further comprising wrapping at least one layer of tape over the second tensile layer and between the second tensile layer and the outer sheath.

28. The method of claim 23 wherein the tubular member is a plastic sheath.

10 29. The method of claim 23 wherein the tubular member is a carbon steel strip.

30. The method of claim 29 further comprising providing a plastic sheath over which the carbon steel strip extends.

15 31. The method of claim 30 wherein the carbon steel strip is helically wound over the plastic sheath.

32. The method of claim 30 further comprising providing a collapse-resistant, inner helical strip within the plastic sheath.

20 33. A method of manufacturing a pipe from a coiled sheet, the method comprising unwinding the sheet from the coil, disposing a plurality of spaced cutters in the path of the sheet as it unwinds from the coil to cut the sheet into a plurality of wires each having a substantially rectangular cross section, and wrapping the wires around a tubular member.

25 34. The method of claim 33 wherein the step of wrapping comprises wrapping a plurality of the wires around the exterior of the tubular member to form a first tensile layer, and further comprising wrapping

a plurality of the wires around the exterior of the first tensile layer to form a second tensile layer.

35. The method of claim 34 wherein the wires of the first tensile layer are wrapped helically around the exterior of the tubular member  
5 and wherein the wires of the second tensile layer are wrapped helically around the first tensile layer in an opposite direction to the wires of the first tensile layer.

36. The method of claim 33 further comprising extruding an outer sheath over the second tensile layer.

10 37. The method of claim 33 further comprising wrapping at least one layer of tape over the second tensile layer and between the second tensile layer and the outer sheath.

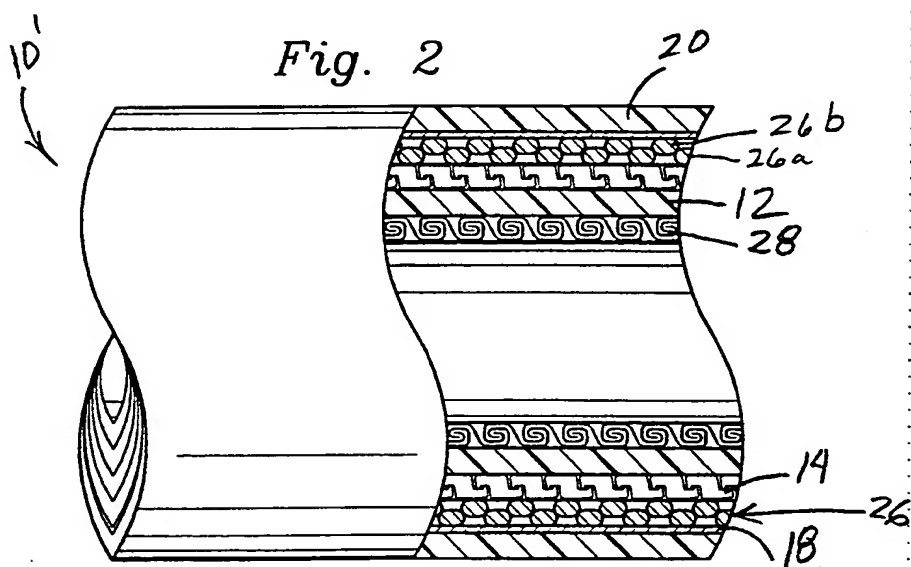
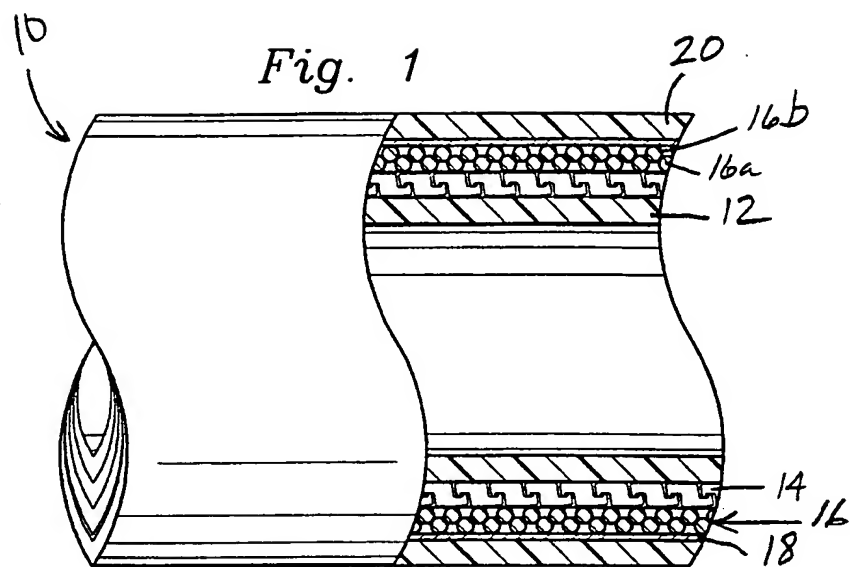
38. The method of claim 33 wherein the tubular member is a plastic sheath.

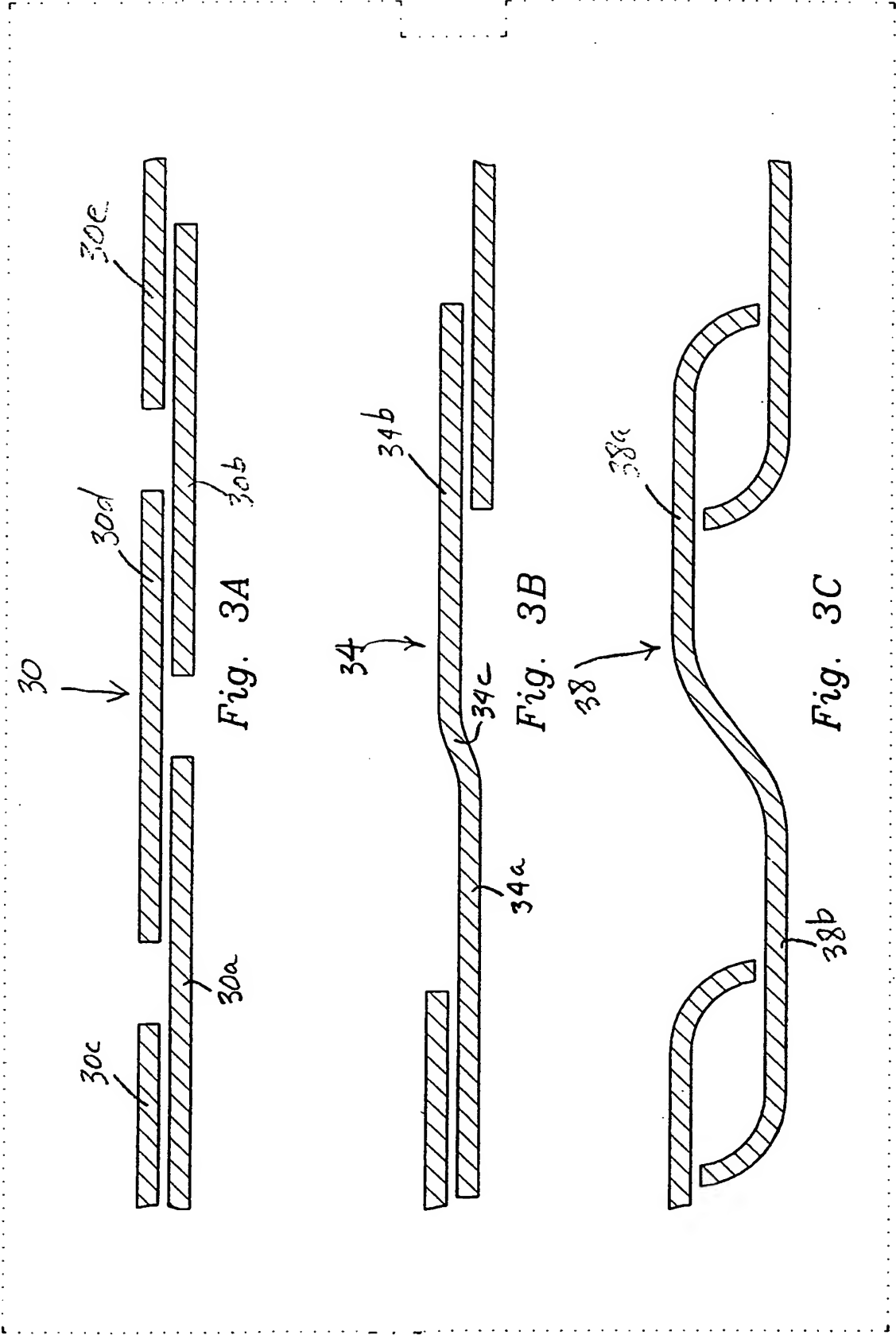
15 39. The method of claim 33 wherein the tubular member is a carbon steel strip.

40. The method of claim 39 further comprising providing a plastic sheath over which the carbon steel strip extends.

41. The method of claim 40 wherein the carbon steel strip is  
20 helically wound over the plastic sheath.

42. The method of claim 40 further comprising providing a collapse-resistant, inner helical strip within the plastic sheath.





## INTERNATIONAL SEARCH REPORT

 International application No.  
PCT/US00/30464

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : F16L 11/10

US CL : 138/135

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 138/135, 124, 125, 126, 127, 130, 144, 121, 122

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST search terms: metal, flattened, wire

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,730,188 A (KALMAN) 24 March 1998, see entire document.	1-42
Y	US 5,579,809 A (MILLWARD et al) 03 December 1996, see entire document.	1-42
Y	US 3,687,169 A (REYNARD) 29 August 1972, see entire document.	7 and 8
Y	US 3,890,181 A (STENT et al) 17 June 1975, see entire document.	23-32
A	US 4,706,713 A (SADAMITSU et al) 17 November 1987, see entire document.	1-22 and 33-42
A,P	US 6,098,667 A (ODRU) 08 August 2000, see entire document.	1-42



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
*B* earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*A* document member of the same patent family
*O* document referring to an oral disclosure, use, exhibition or other means	
*P* document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

12 MARCH 2001

Date of mailing of the international search report

04 APR 2001

 Name and mailing address of the ISA/US  
Commissioner of Patents and Trademarks  
Box PCT  
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

JAMES F. HOOK

Telephone No. (703) 308-0870